Systems of Innovation and Innovation Ecosystems: a literature review in search of complementarities

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Abstract

This paper aims to clarify to what extent the emerging theory of innovation ecosystems (IE) and the theory of systems of innovation (SI) are complementary and then identify how its communities could benefit from cross-fertilization. We performed a critical literature review of both topics using meta-synthesis as method to identify, analyze and compare the two theories. Using a framework, this paper explores the elements belonging to each theory's domain, in order to identify the key factors necessary to compare the two theories. The results of this analysis show that both theories involve the assessment of three key aspects: the understanding of innovation activities, the role of the agents involved, and the interaction and resulting networks among them. A similarity was found showing that these two different theories are applications of System Thinking approach. Another finding, which has not been mentioned in previous research on the topic, is that the construction of the initial concepts of the IE theory was originally rooted in several SI elements. Finally, we found key factors that may be the cross-fertilization link between the two communities that represent each theory.

Keywords: innovation ecosystems, systems of innovation, technology innovation

JEL Classification: B52 • O32 • O35 • P13 • P51

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1. Introduction

Developing technologies emerge within a complex context of interactions among different stakeholders, including industrial players, investors, entrepreneurs, scholars and governments. In some cases, these technological innovations are based on platforms where the interactions take place through massive data exchange between machines, such as the IoT (internet of things) and machine-to-machine systems (Moore, 2013). Leveraging the business opportunities from these new technologies often requires new business models that have a strong interdependence with the value chain and that have increasingly shorter life cycles (McKinsey, 2013, 2015; OECD, 2013; Wyss Institute, 2011). This economic scenario is characterized by the combination of three interconnected factors: (i) the increasing ease at transcending borders (internationalization), (ii) the removal of artificial trade barriers (liberalization) and (iii) the increasing ability to exchange data using information technologies (Hayes, Gary P. Pisano, David M. Upton, & Wheelwright, 2004; Strikwerda, 2010; van der Zee & Strikwerda, 1999). The global market also adds several other complexities for emerging technologies, related to security, regulation, logistics and legal compliance (OECD, 2013, 2015; Warwick, 2013).

A vast array of theories provide explanations for the specific phenomena found within the field of innovation. In the midst of this complex and ever-changing scenario, scientific communities and industrial sectors must ask themselves, after all, how to benefit from resources (methods, techniques, instruments, etc.) and discoveries provided by other research communities that operate in the same field of research. Fully established theories as SI[2] have reached stages of maturity characterized by a certain self-criticism in which even fundamental concepts are questioned. A good example of this is the article "National innovation systems - analytical concept and development tool" on the maturity of SI theory from Lundvall (2007a). On the other hand, emerging theories such as IE are still constituting their concepts, developing new models of understanding, proposing tools and creating their agendas and research groups (Rong & Shi, 2015). Part of this self-affirmation process consists of differentiating itself from contiguous theories. In this vein, our motivation with this article is to clarify to what extent the theories of innovation

[2] In the literature, the terms "National/Regional Innovation Systems," "Systems of Innovation" and "National/Regional Systems of Innovation" are used interchangeably. In this paper, the term "Systems of Innovation" (SI) is used to refer to all these terms.

ecosystems (IE) and systems of innovation (SI) differ and are complementary to one another, and then identify how communities could benefit from cross-fertilization.

To that effect, the article was structured according to the AIM(RaD)C convention (Cargill, 2009). Thereby, the article begins with its abstract, develops an introduction (session 1), presents the methodology (session 2), which is applied with the support of a comparative framework of theories to perform a review of the SI theory (session 3), of the IE theory (session 4) and a comparative analysis of theories in search of complementarities (session 5) structured between literary review, followed by a summary in table format with the results found in the literature. The article ends with some conclusions (session 6).

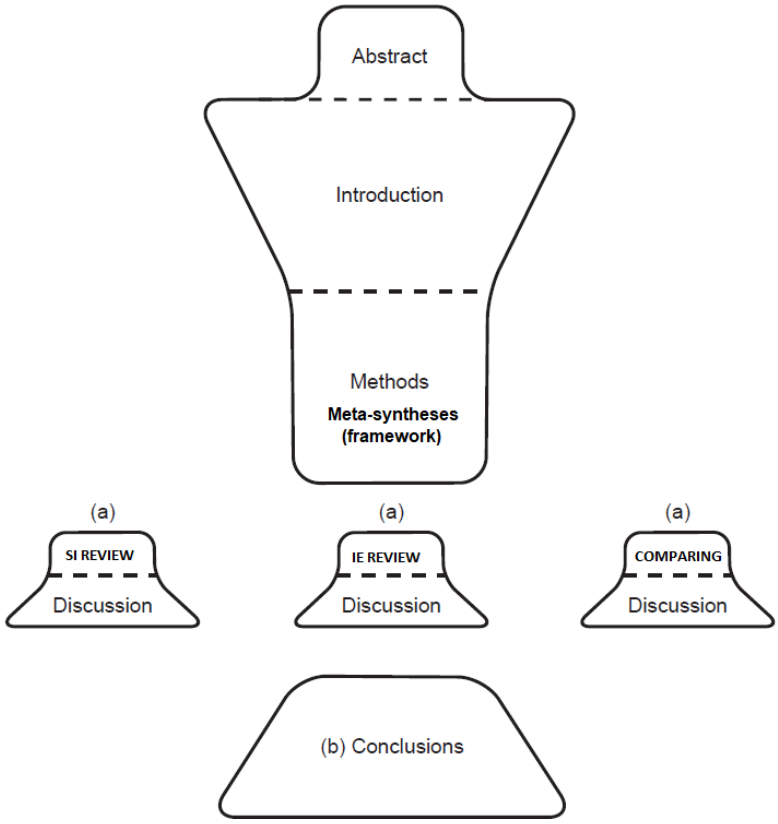

Figure 1 - The article structure

(a) The Results and Discussion are presented together in a single combined section.

(b) This means that a separate section is needed at the end to bring the different pieces (SI Review, IE Review and Comparing) of discussion together.

2. Research Methodology - Meta-Synthesis

Given our motivations, this paper is clearly a literature review. This review aims to identify the main elements of scientific production that characterize the bases of the two theories under study and, from there, to seek points of interaction and complementarity between them and consequently find elements of cross-fertilization. According to a number of authors (Ackerson, 2007; Cronin, Ryan, & Coughlan, 2008; Grant & Booth, 2009), there are fourteen different types of literature review, which must be chosen from according to the overall aims and objectives of the review.

The method chosen for this paper is meta-synthesis research method. Meta-synthesis is a non-statistical technique used to integrate, evaluate and interpret the findings of multiple qualitative research studies (Cronin et al., 2008). Meta-synthesis involves analyzing and synthesizing key elements of each concept, based on the identification and analysis of fundamental and seminal works, in order to transform individual findings into conceptualizations and interpretations (Polit & Beck, 2014).

Given that both theories in focus here are related to grounded theories (Lundvall, 2007b; Parisot & Thierry, 2017a), where such works exist, meta-synthesis is the most appropriate method for a systematic comparison of the IE and SI (Zimmer, 2006).

The literature review was restricted to the main authors of both theories under study, and also in articles derived directly from the founding authors of the theories presented in this paper. Articles that do not base their research on the foundations of SI or IE theories were not considered, in spite of the use of similar analogies, approaches and metaphors with the same terms or meanings used in SI and IE theories.

In order to identify which variables would be the most important for the comparative literary analysis of the two theories, an ontological framework was used to give structured support to the key elements that constitute the logical and fundamental architecture of each theory. The variables chosen from the comparative purpose of the literature review based on meta-synthesis are presented in Table 1 that identifies the fundamental themes for a comparison of theories and the key factors for a detailed analysis.

The integrated results of the two analyses are presented in one ontological framework in order to highlight the key factors necessary to compare the two theories (Figure 1). In the SI review, the

seminal works reviewed were of those of Lundvall, Freeman and Nelson, the three "founding fathers" of the concept, combined with other conceptual publications (review papers or theoretical essays). In the case of IE, the seminal works are the three main publications of Moore on Business Ecosystems, combined with other conceptual publications that build upon Moore's definitions.

It is worth clarifying that, in our review of the literature many articles (especially the most cited in the subject) treat business ecosystem (BE) and innovation ecosystem (IE) as interchangeable terms (Adner, 2006; Adner & Kapoor, 2010; Gawer & Cusumano, 2014; Gawer, Annabelle, 2014; Gomes, Facin, Salerno, & Ikenami, 2016; Kapoor & Lee, 2013; Nambisan & Baron, 2013; Overholm, 2015; Zahra & Nambisan, 2012).In this sense, and considering that this is already an established fact in the research community in BE we will use the same semantic between the terms always considering the restricted use of authors who derived or evolved their research based on the essential elements of the theory of BE.

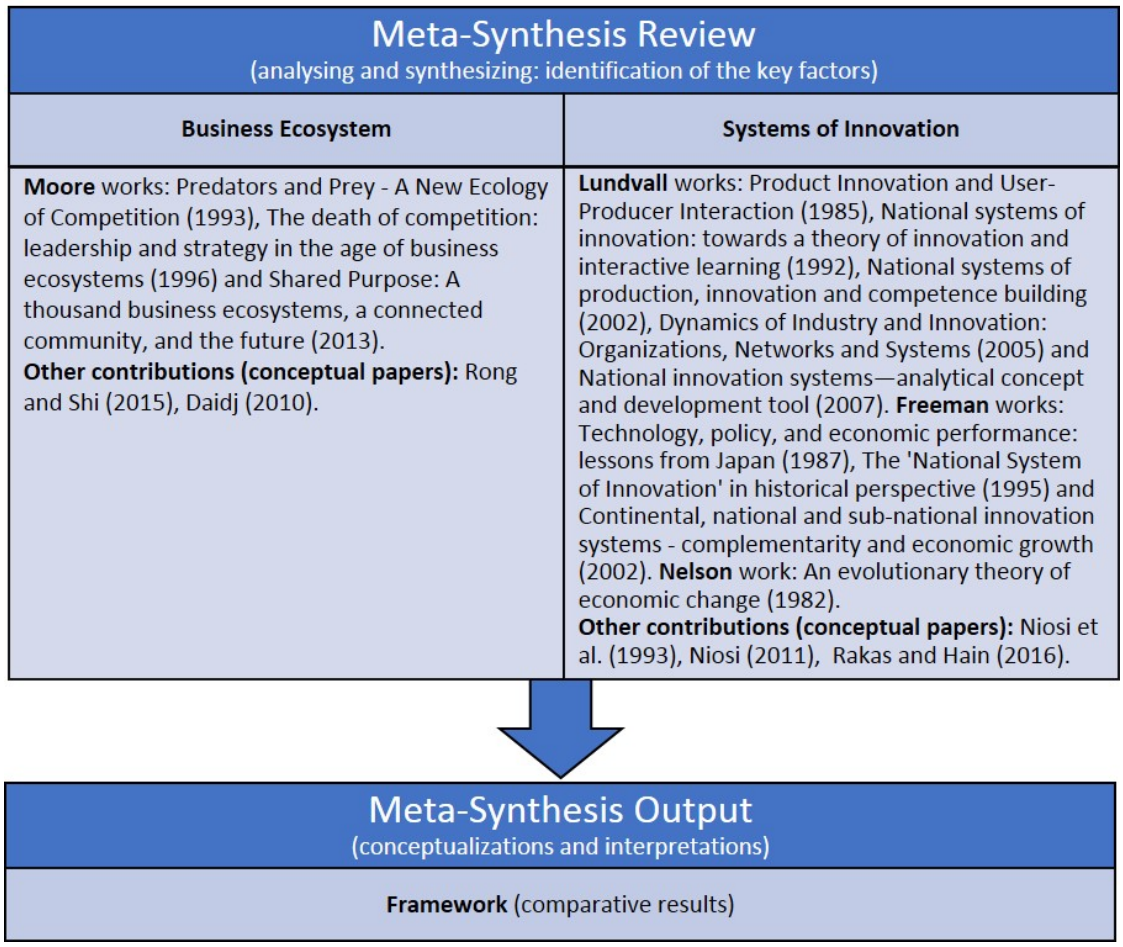

Figure 2 – Meta-synthesis methodology

Through the meta-synthesis literature review methodology, the three "fundamental theoretical themes" that were identified as relevant for comparing IE and SI theories are **concepts**, **literature** and **framework structure**. These key areas and their factors are presented in Table 1. Note that these areas of comparison are explored in detail later in this work.

Fundamental theoretical themes	***Key factors***
Concepts	Key concepts, Synonyms, Related terms, Target of the concept, Scope application area and Logic unit
Literature	Seminal works, Key authors, Key topics, Authors who evolved the concept, Universities involved, Case, Heritage and Some inspirations
Framework structure	Scientific approach, Core discipline, Theoretical basis, Boundaries, Network boundaries, Industry role, Approaches to analyzing

Table 1 - Key factors necessary for the comparison of the SI and IE theories

3. Systems of Innovation Review

3.1. Antecedents

The concept of SI emerged in the late 1980s, coined by Freeman to describe the congruence in Japanese society (Soete, Verspagen, & Weel, 2009) between various kinds of institutional networks in "private and public sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987). In line with earlier work on long waves of economic and technological development (Soete et al., 2009), Freeman's focus is on the broad interaction between technology, social embedment and economic growth and feedback loops reinforcing the system (Soete et al., 2009). Freeman's contribution was followed a year later by a book edited by Dosi (1988), which included three chapters on the SI concept as proposed by Freeman, Lundvall and Nelson.

3.2. Systems of Innovation as a System Approach

The systems approach to the analysis of economic and technological change is not new (Carlsson, Jacobsson, Holmén, & Rickne, 2002). Several systems approaches have been developed in order to analyze technological innovation as a system. A system is a set of interacting elements with

interrelationships among them (Bertalanffy, 1969) along with a combination of those interacting elements organized to achieve one more stated purpose (INCOSE, 2006). According to Carlsson et al. (2002), systems are made of components, relationships and attributes. Social systems are interrelated sets of practices, institutions and roles (Niosi, 2011; Niosi, Saviotti, Bellon, & Crow, 1993). From an economic perspective, one of the first concepts of systems SI emerged from the work of List (1841). His concept of national systems of production and learning took into account a wide set of national institutions, including those engaged in education, training and infrastructure, such as transportation networks for both people and commodities (Freeman, 2002; Lundvall, Johnson, Andersen, & Dalum, 2002), and was a counterpoint to the liberal economic model that was the dominant theory at the time.

One hundred years after Friedrich List's book, Leontief (1941) published "The structure of American economy - an empirical application of equilibrium analysis". In this work, the approach of "analysis of production systems with innovation" was developed as an analytical tool focusing on sectors of the economy (Lundvall et al., 2002). Over the following years, other approaches were developed as tools for analysis of innovation systems. Among them, the most widely known is the "Innovation System."

3.3. Systems of Innovation as a Theory

Initially, the SI concept was introduced as "Innovation Systems" by the evolutionary economist Bergt-Åke Lundvall (Freeman, 1995). Based on the joint work of Lundvall, Freeman and Nelson, it became "Systems of Innovation" (Dosi, 1988).

In more general contexts, this theory remains known as "Systems of Innovation"; however, when applied to specific geographical regions, it is also known as "regional systems of innovation (RSI)" or "national systems of innovation (NSI)" when it analyzes the economy of a whole country. Other systems operating at the national level are referred to as "social systems of innovation" and "national business systems."

Two definitions of the term SI from the theory founders, among the various found in the literature, have become the most widespread, according to the Organisation for Economic Co-operation and Development, OECD (1997). The first one defines SI as *"the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge (...) and*

are either located within or rooted inside the borders of a nation state" (Lundvall, 1992). The second states that SI is *"the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies*" (Freeman, 1987). Besides these two definitions, there are two others that are often used to introduce the concept. Metcalfe (1995) defined an SI as "that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies". Finally, Patel (1994) defined it as "the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country".

The main co-authors of the evolution of the term SI were Freeman, Nelson and Lundvall, through chapters of the book "Technical change and economic theory" (Dosi, 1988). Based on empirical studies giving strong emphasis to people, organizations and competence, the term SI reflects a grounded theory as a scientific approach, though the "scientification" of the term was not the purpose of the "founding fathers" of the theory.

The theory "Systems of Innovation" is a combination of four elements: 1) the neo-Schumpeterian reinterpretation of national production systems, 2) empirical work based on the home-market theory of international trade, 3) the microeconomic approach to innovation as an interactive process and 4) insights in the role of institutions in shaping innovative activities.

The two main areas of application and contribution for SI derive from these elements. The first two elements concerns regional development and public policy for science, technology and innovation (Edquist, 2001); (Boschma, 2004). The other two elements build upon the assessment of knowledge flows, which is a central issue in the SI study (OECD, 1997). Therefore, SI studies have a significant contribution to the knowledge management literature, specially for the identification and assessment of the importance of new types of knowledge and their respective flows within an SI. Some of the types of knowledge include tacit versus explicit knowledge (Cooke, Uranga, and Etxebarria (1997), STI (science-technology-innovation) versus DUI (doing-using-interaction) (Jensen, Johnson, Lorenz, & Lundvall, 2007) and knowledge produced in a

disciple-specialized mode (mode 1) versus one produced in a transdisciplinary-networked mode (mode 2) (De la Mothe & University of Ottawa 2001).

3.4. Specialization of the SI theory

In "National innovation systems – analytical concept and development tool," Lundvall (1992, 2007b) clarified that, since it takes on different meanings in different contexts, the NIS concept is not simply a theoretical concept. Rather, the NIS offers a broad and flexible framework for organizing and interpreting case studies and comparative analyses. It is natural then that the SI theory would be strengthened by new theoretical elements and specialization fields.

One notable example is the innovation taxonomy, drawn from the works of Pavitt (1984) and Leontief (1941), which uses an analogy taken from Darwin's evolutionary theory applied to an economy, a common practice among evolutionary economists (also a constant, by the way, within the IE theory). Beyond policy making, Pavitt's taxonomy contributed to a variety of fields within innovation studies (Archibugi, 2001), including organizational behavior and business process mapping at the firm level. The main contribution of the taxonomy is the view that no one-fits-all model would do in organizing and understanding the processes of innovation and technological change.

Another important addition to the SI theory is the triple helix model (Etzkowitz & Leydesdorff, 1995), which found its inspiration in the Sabato and Botana triangle (Sábato & Botana, 1968). This model contributed largely to the understanding of the complementarities of the main agents of an SI from both the public policy and knowledge management perspectives (Ranga & Etzkowitz, 2013).

Through other researchers, contributions were developed with focus on different perspectives:

- Technological systems (Carlsson & Jacobsson, 1994)
- Regional systems of innovation (Cooke et al., 1997)
- Sectoral systems of innovation (Breschi & Malerba, 1997)
- Industrial clusters (Porter, 1990).

Some of the most comprehensive research on the different approaches of SI was developed in "The development of Innovation System Research: Towards an Interdisciplinary and Multidimensional Approach?" (Rakas & Hain, 2016). In this article, the researchers showed the intensive

interdisciplinarity of these approaches and highlighted the increase in the studies of SI with a focus on management and organization of innovation, which primarily focuses on a firm-level analysis.

According to Rakas, and Hain (2016), new approaches were developed based on the seminal works of Nelson, R. R. (1993), Freeman (1987) and Lundvall (1992). These approaches differ by analytical and conceptual focus, elements and dimensions emphasized, and system boundaries and units of analysis. The most frequently used units of analysis are regional, sectoral, technological, business and social systems of innovation and production.

Finally, it is important to recall that the "(…) focus on innovation systems is less reflecting a theoretical abstraction and more the practical needs of the participants in the complex division of productive and innovative labour in modern economies." (Lundvall et al., 2002). However, as one may infer from its applications and later definitions, the focus has been given to the "practical needs" of local policy makers (government) to attract and retain innovative players to a specific region or country, and for boosting innovative performance therein.

4. Innovation Ecosystems Review

4.1. Antecedents

Today's industry is divided into a large number of segments, each producing specialized products, services and technologies. The degree of interaction between firms in a given industry is astounding, with hundreds of organizations frequently involved in the design, production, distribution or implementation of even a single product (Iansiti & Levien, 2004). In this context, a business cannot be considered relevant only from a sectoral viewpoint (Moore, 1993, 1996), but rather must be viewed as an entity belonging to something bigger, more complex and borderless, which we call the Business Ecosystem (Daidj, 2010, 2011; Rothschild, 1990).

The use of the analogy between business and an ecosystem was first used in the book of Rothschild (1990) "Bionomics: The Inevitability of Capitalism." Numerous other publications adopted the same analogy, though from different perspectives. Among the several analogies that emerged, the best known are the industrial ecosystem, digital business ecosystem and entrepreneurship ecosystem (Pilinkienė & Mačiulis, 2014). These analogies have been used in many publications in the form of metaphors and similarities. Yet, despite how often these terms are used in research,

there is no apparent agreement on how they are defined and how they should be applied (Bechtel, 2009). In addition, the terms often appear interchangeable and are often used inappropriately. In order to understand the concept of BE, it is essential to understand its origins, semantics and constructs, as well as the current research on the topic.

4.2. Innovation Ecosystem as an Analogy

Rothschild's theory (1990) considers capitalism as the evolutionary result of organizations (businesses, corporations, markets, economies) seeking to preserve themselves through adaptation to the environment and through the "genetic" inheritance of successful characteristics. Rothschild (1990) says that, in a business ecosystem, two factors are essential to determine the pace of evolutionary change: technical innovation and market competition. One of his major contributions was his vision of the economy as an ecosystem, in which organizations are nodes in a network of relationships constrained by the key relationships in their environment. Rothschild established his analogy without any commitment to scientific rigor, but rather as a means of establishing a logical understanding of his vision of economic evolution and the competitiveness of capitalism. In his words, “for the analogy between ecosystem and economy to be useful, it need not be perfect”.

It is important to note that many in-depth studies were developed between 1941 and 1948 that used the same analogy, with organization networks as living systems (Angyal, 1941; Feibleman & Friend, 1945; Selznick, 1948). These studies are part of the “fundamentals” of various fields of knowledge, such as Systems Engineering, Cybernetics, Operation Research, Decision Theory and Systems Thinking (Minati, Abram, & Pessa, 2016).

4.3. Innovation Ecosystem as a Theory

IE as a concept was first proposed by Moore (1993), and was referred to as “Business Ecosystem” (BE). The concept was developed with a logic unit of analysis focused on "business opportunities" through the interactions of competition and co-operation. Moore (1993, 1996) reference to the evolutionary concept of BE was based on the following works: Nelson, R., and Winter (1982), Anderson (1989), Rothschild (1990), Henderson (1989) and, more particularly, Astley, and Fombrun (1983) and Astley (1985). The philosophical inspiration of Moore's work was based on the Gregory Bateson book, “Mind and Nature” (Bateson, 1979). In terms of biology and evolution

as technical constructs of the "business ecosystem" concept, Moore built his metaphor (Moore, 1993, 1996, 1998) using the work: “The Diversity of Life” authored by Wilson (1992).

In his first publication on the subject, Moore defined “business ecosystem” as “an economic community supported by a foundation of interacting organizations and individuals — the organisms of the business world” (Moore, 1993, 1996). As an introductory concept, it is clear that several entities are related in the context of “the business world.” Moore’s research was based on the competitive technology environment, focusing on leadership and strategy. He thus presented concepts focused on business opportunities. Some of the companies that were part of Moore's research were AT&T, GeoPartners Research Inc, Intel Corporation, Hewlet-Packard, Royal Dutch Shell Group and Sun Microsystems. In the context of “the economic community,” Moore (1996) says, “The economic community produces goods and services of value to customers, who are themselves members of the ecosystem.” This shows his intention of proposing the BE as a network oriented towards the value delivered to customers. “The member organisms also include suppliers, lead producers, competitors, and other stakeholders” (Moore, 1996). The inclusion of competitors as part of the same ecosystem is an innovative concept among the various models for business network analysis.

“Over time, they (ecosystem participants) co-evolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies” (Moore, 1996). To thrive over time, the system (ecosystem management) must adapt to changes in the business environment through the intentional acts and coordination efforts of managers and entrepreneurs (Teece, 2015). According to Moore (1996), “those companies holding leadership roles may change over time, but the function of the ecosystem leader is valued by the community because it enables members to move towards shared visions to align their investments, and to find mutually supportive roles.” These ecosystems have no fixed boundaries, and they are in dynamic movements of co-evolution together with other members of the business ecosystem (Gueguen & Torrès, 2004). In the same way, Torre, and Zimmermann (2015) define IE as an economic environment with reciprocal exchanges, with different types of relationships acting as a system of interactions. However, one striking feature of IE theory is that it assumes that the sharing of skills and roles may happen, in some cases, even without leadership hegemony.

It is important to mention that in IE, long-term wealth is determined by relationships rather than by transactions (Kandiah & Gossain, 1998). In terms of shared capabilities, Remneland, and Wikhamn (2013) add that IE can enable a value creation strategy conducted outside the boundaries of the company through the structuring of an open innovation model. Likewise, Gawer, and Cusumano (2014) claim that in a IE, "the value co-creation process is set to create more value for the ecosystem's end users, together, than the individual players could generate as independent actors."One of the deepest and richest research works developed recently was the publication, "Understanding Business Ecosystems." This work evolved as a result of three annual round tables on ecosystems: the International Association of Strategic Management (AIMS) in 2010 and 2012, and the Administrative Sciences Association of Canada Conference (ASAC) in 2011 (Letaifa, Gratacap, & Isckia, 2013). The goal of this work was to develop an integrative synthesis of the various issues identified during these academic events.

Many other contributions were made over the last few years. The latest research comes from Shi and Rong. Their case studies allowed the publication of the first step in the construction of a Theory of Business Ecosystems. This work systematically examines innovation ecosystems in an emerging industry context while fundamentally exploring and identifying four essential areas of innovation ecosystems: the innovation ecosystems' key constructive elements, their typical patterns of element configurations, the five-phase process of their life cycle and the nurturing strategies and processes from a company perspective (Rong & Shi, 2015). Their previous contributions include the proposal of "the 6C framework," used to analyze the data collected from case companies and to identify three patterns of IoT-based innovation ecosystems (Rong, Hu, Lin, Shi, & Guo, 2015; Rong & Shi, 2009; Rong, Shi, & Yu, 2013; Shi, Fleet, & Gregory, 2003).

Finally, the most solid and current researches that have contributed to the evolution of the theory of ecosystems of innovation are from two recent articles: "*La théorie substantive des écosystèmes d'affaires selon James Moore*" authored by Parisot, and Thierry (2017b) and "*Une lecture Lakatosienne de l'approche par les Ecosystemes d'affaires*" also from the same authors (Parisot & Thierry, 2017a). Based on previous research by Edouard, and Gratacap (2011), its authors develop a careful analysis of the process of Moore's theorization in ontological, epistemological and methodological terms. Parisot, and Thierry (2017b) present a meticulous mapping of the main specializations (hypotheses) of concepts and theory of IE published in articles from the year 1993

to 2014, pointing out that the approach of Innovation Ecosystems constitutes an important theoretical and conceptual advance in the field of strategic management.

4.4. Comparison of Different Ecosystem Analogies

The BE concept proposed by Moore evolved during the Internet bubble (or dot-com bubble). This event was one of the key references in Moore's studies, as its negative effects were still being felt in the Silicon Valley between 1990 and 1993 and had prompted new business strategies. In that same period, new cross-industry relationships and new alternatives for production emerged. As well, a wave of startups, the emergence of new business models and new technologies, such as the Internet of things, Cloud services and 3D printers, emerged. All of these factors created new and more complex networks of business, with interactions that resulted in yet new products and services.

Between 2002 and 2004, Marco Iansiti, Professor at Harvard Business School, and his collaborators defined new concepts in the structure and dynamics of an IE, including defining the different roles of actors in an IE and their strategies (Iansiti, 2004; Iansiti & Levien, 2002; Iansiti & Levien, 2004; Valkokari, Seppänen, Mäntylä, & Jylhä-Ollila, 2017). Iansiti, in his book entitled "The Keystone Advantage", describes a way for organizations to understand how complex business networks behave, and to explore the possibilities for strategy formulation, innovation and operations management.

Between 2001 and 2004, Nachira, Nicolai, Dini, Le Louarn, and Leon (2006) developed the concept of Digital Business Ecosystem (DBE), which was targeted to technology SMEs (small and medium-sized enterprises). A year later Moore began to use the term DBE of this research. The research related to DBE was triggered by Go Digital and was aimed at boosting ICT adoption by European SMEs. Nachira's research refers to a new interpretation of "socio-economic development catalyzed by ICTs," emphasizing the co-evolution between the IE and its partial digital representation - the digital ecosystem. A year later, Moore began to use this term in his research.

Between 2004 and 2006, two main contributions came from Peltoniemi, and Vuori (2004) and Peltoniemi, Vuori, and Laihonen (2005): the five key features of a innovation ecosystem (Complexity, Self-organization, Emergence, Co-evolution and Adaptation) and a proposed

governance framework by adopting system complexity and evolutionary theory. In the period between 2004 and 2013, Den Hartigh and his colleagues suggested new types of roles, governance framework and ecosystem health measurement (Anggraeni, den Hartigh, & Zegveld, 2007; Stolwijk, Ortt, & den Hartigh, 2013).

Between 2006 and 2013, Adner and his colleagues regarded the innovation ecosystem as the structure of technology interdependence (Adner, 2006; Adner & Kapoor, 2010; Leavy, 2012). In 2012, Adner developed the idea of Value Creation in Innovation Ecosystems in his work, "The Wide Lens: What Successful Innovators See That Other Miss" (Adner, 2012). Adner (2012) in his book clearly states that his work is a continuation of Moore's work. One of the purposes of his work was to answer such questions as, "how the structure of technological interdependence affects firm performance?" and "how to develop an innovation strategy in an innovation ecosystem?"

In 2015, in a research conducted by Rong, and Shi (2015) a comparative analysis of theories took into account two trends considered as potential challenges in the context of manufacturing industries: interoperability and uncertainty. The case study was based on a mobile computing industry. Among the various theories (GMVN, Business Network, Suply chain, International Strategic Alliance, Industry Cluster and others), IE has been identified as the theory most apt to tackle the challenges of today's emerging industries.

Finally, the IE analogies are summarized in a comparative table from the paper "Comparison of Different Ecosystem Analogies," by Pilinkienė, and Mačiulis (2014). This table presents a comparison of the different conceptual variations that emerged from publications on innovation ecosystems. Not all of them have links to Moore's theory of IE.

ECOSYSTEM ANALOGIES	INDUSTRIAL ECOSYSTEM	INNOVATION ECOSYSTEM	DIGITAL BUSINESS ECOSYSTEM	ENTREPRENEURSHIP ECOSYSTEM
ENVIRONMENT	Local; industrial environment	From local to global; inter-organizational, political, economic and technological environment	From local to global; digital environment	Local; specific location
ACTORS	Manufactures and consumers	Entrepreneur; large and small enterprises; educational institutions; research institutions and laboratories; venture	Research and education organizations; innovation centres; small and large enterprises with their	Financial capital; educational institutions; culture; support measures; human capital; markets; government institutions; nongovernment

		capital firms; financial markets; government institutions	associations; local government and public administration	institutions; entrepreneur; large and small enterprises
KEY DETERMINANTS AFFECTING ECOSYSTEM PERFORMANCE	Industry and environment interaction; interaction between ecosystem actors	Resources, governance, strategy and leadership, organizational culture, technology. interaction between ecosystem actors	Services and technological solutions, business and knowledge; interaction between ecosystem actors	Opportunities, skilled people and resources; interaction between ecosystem actors

Table 2 - Comparison of different ecosystem approaches - adapted from Pilinkienė, and Mačiulis (2014)

5. Comparative Analysis between the theories

5.1. Comparative Analysis: Concepts

Moore (1993, 1996) coined the term business ecossytem as "an economic community supported by a foundation of interacting organizations and individuals. " It is a dynamic structure, centered on a given firm, composed of a population of interconnected organizations in a common technology platform (Peltoniemi and Vuori, 2004), which goes beyond the core business agents (direct suppliers, core contributors and distribution channels) to embrace its whole supply chain, as well as other indirect agents and stakeholders. Business ecosystem is the evolution and an extension of the traditional concepts of a business value chain, cluster and value networks (Daidji, 2011; Torre and Zimmermann, 2015). Likewise, the SI approach "stresses that the flows of technology and information among people, enterprises and institutions are key to the innovative process (…) [which is] the result of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes." (OECD, 1997). However, the center of the analysis is not an individual firm, but the location (a region or a country) to which it belongs (Patel and Pavitt, 1994). In this way, we can clearly see that both the IE and SI theories are distinct from one another, not only in semantics, but also in structure. Though both terms are directly linked to the study of innovation, they differ in terms of prospects, actors, results, relationships and distinct criteria. Regarding audiences and logic units of analyses, even though IE and SI are complementary in the study of innovation, each theory focuses on a distinct public.

While SI helps "policy makers develop approaches for enhancing innovative performance in the knowledge-based economies" (OECD, 1997), IE was developed to "help executives anticipate the managerial challenges of nurturing the complex business communities that bring innovations to market" (Moore, 1996). While both theories analyze interactions in networks, IE is focused on the

development of business analysis in order to develop business strategies. On the other hand, SI is dedicated to understanding the flow of information and knowledge related to the technological development of a nation or specific region.

Table 3 - Comparative Meta-Synthesis Framework: Concepts

Concepts	***Comparative framework***	
	SI	**IE**
Key concepts	"...The elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state" Lundvall (1992)	"An economic community supported by a foundation of interacting organizations and individuals — the organisms of the business world" Moore (1993)
Synonyms	National Systems of Innovation (NSI) Innovation Systems (IS) Systems of Innovation (SI) National Innovation Socio-Economic Formations Regional Systems of Innovation (RSI)	Business Ecosystem (BE) Innovation Ecosystem (IE)
Related terms	Social systems of innovation National business systems Technological systems Regional systems of innovation Sectoral systems of innovation	Innovation ecosystem Digital ecosystem Software ecosystem Platform ecosystem Entrepreneurship ecosystem Industrial ecosystem Economic ecosystem Bionomics
Target of the concept (explicitly defined by the creators of the concepts)	Policy makers Policy institutions (OECD, UNCTAD, World Bank, EU-Comission etc.) Policy analysts Scholars Practitioners	Businessmen Entrepreneurs Investors
Scope application area – (predominance)	Policy strategy	Business innovation strategy
Logic unit	Knowledge centric or information flows centric: Joint industry activities, public/private interactions, technology diffusion and Personnel mobility	Opportunity environment Business Centric Shared Purpose Platforms Supply systems Communities of destiny Expanding communities

Relationship between technology, socio-economic structures and institutions Technological and economic performances Institutional set-up

5.2. Comparative analysis: Literature

The most striking difference between the terms IE and SI is their use in distinct subject matters. The SI articles are found in scientific journals devoted to the study of evolutionary economy and innovation economy. On the other hand, publications on the IE theories are predominantly found in journals focused on the study of competitive strategies in the management world.

Key author and key topics in SI – Christopher Freeman was an English economist, the founder and first director of Science Policy Research Unit at the University of Sussex, and one of the most eminent researchers in innovation studies (Toporowski & Freeman, 2010). His fields of specialization were the economics of innovation and technical change. In 1986, on his formal retirement, he became visiting professor at the Aalborg University in Denmark. Freeman introduced the concept of National System of Innovation with B. Å. Lundvall and Richard Nelson (Lundvall, 2007b).

All three devoted their research on the following topics: technical change, science and technology indicators, the diffusion of technologies, structural change in the world economy and management of innovation.

Key author and key topics in IE – James F. Moore studies co-evolution in social and economic systems. He is best known for pioneering the IE theory to study networks of organizations (Steven, 2013).

Moore argues that IE is an essential unit of analysis for competition law, economics, sociology and management (Moore, 1996). His works involve an in-depth study of the multiple and interconnected nanoscience, semiconductors, systems-on-chips, global telecommunications services, smartphones and Internet-of-things devices, and app ecosystems (Moore, 2013). According to an analysis carried out on the works of the founding authors of both terms, much of the confusion arises from the fact that all of them have an interest in the study of innovation within a context of networks of relationships from an economic point of view. Yet another point of similarity is that the researchers of both IE and SI analyze the interactions between the actors involved in the systematic innovation process.

IE Cases – The creators of the terms IE and SI devoted their time on case studies related to their respective areas of research. Moore analyzed the technological strategies of companies such as Intel, Qualcomm, NVIDIA, Samsung, ARM Holdings, IBM, Apple, Facebook, Google, Microsoft and Amazon.

The main studies on the formulation of "IE theory" were based on a technological leadership study of the following companies: ABB Canada, Silicon Valley, Intel Corporation, Hewlet-Packard, Royal Dutch Shell Group and Sun Microsystems.

SI Cases – B. A. Lundvall, R. Nelson and C. Freeman studied the reality of the innovation process in specific countries. In 1987, Freeman published the book "Technology Policy and Economic Performance" on the development of the national innovation system in Japan. Nelson's studies focused on the USA (Dosi, 1988), while Lundvall (1985) focused on Europe.

Table 4 - Comparative Meta-Synthesis Framework: Literature

Literature (sources)	***Comparative framework***	
	SI	**IE**
Seminal works	National systems of innovation: towards a theory of innovation and interactive learning (Lundvall, 1992)	Predators and Prey - A New Ecology of Competition (Moore, 1993)
Key authors	B. A. Lundvall, R. Nelson, C. Freeman	J. F. Moore, R. Adner, M.A. Cusumano and A. Gawer, M. Iansiti and R. Levien
Key topics	Theory of Innovation Interactive Learning	Strategy, Innovation, Leadership
Authors who evolved the concept	Amable, and Barré (1997) Breschi, and Malerba (1997) Carlsson, and Jacobsson (1994) Edquist (2001) Fagerberg, Mowery, and Nelson (2004) Freeman (1987) Pavitt (1984) Nelson, R., and Winter (1977) Whitley (1994)	Adner (2006) Gawer, Annabelle (2012) Basole, Clear, Hu, Mehrotra, and Stasko (2013) Battistella, Colucci, De Toni, and Nonino (2013) Cusumano, and Gawer (2002) Daidj (2010) Florian Urmetzer (2014) Fréry, Gratacap, and Isckia (2012) Gueguen, and Torrès (2004) Iansiti, and Levien (2002) Letaifa et al. (2013) Peltoniemi, and Vuori (2004) Rong, and Shi (2009) Teece (2015) Torre, and Zimmermann (2015) Visnjic, and Neely (2012) Parisot, and Thierry (2017b)
Universities involved (research communities)	Aalborg University, Tsinghua University, SPRU (UK), Stanford University	Harvard University (Berkman Centre for Internet & Society), University of California – Berkeley, University of Cambridge (Cambridge Service Alliance)
Case	IKE-group, DISKO-project, NIS from Denmark, Sweden, Finland and Japan	ABB Canada, Silicon Valley, Intel Corporation, Hewlet-Packard, Royal Dutch Shell Group and Sun Microsystems
Heritage (historical emergence of the concept idea)	"The National System of Political Economy" (List, 1841)	"A Logic of Systems" (Angyal, 1941)

Some inspirations	**According to** Lundvall (2007b): Neo-Schumpeterian theories French structuralist Marxists Pavitt Taxonomy Interactive process inspired by research at SPRU Psychological pragmatist school of Chicago	**According to** Moore (1996): Inspired by Complex Systems Bateson's ecological Darwinist view Economic evolutionary theories of Nelson, R., and Winter (1982) System thinking

5.3. Comparative Analysis: Framework

Considering the term *framework* as a set of ideas or facts that provide support for a theoretical structure, the meta-synthesis developed in Table 5 compares the essential elements that characterize the theoretical framework of IE and SI.

Scientific theory - In the analysis of technological innovation, there are many ways to represent the environment, actors and strategies. In the context of inter-company relationships, the cluster (El Sawy & Pereira, 2013a, 2013b) and the network value (Rong, Lin, Shi, & Yu, 2013) models are the most used. IE distinguishes itself from these traditional models by also considering other network attributes, such as self-organization, emergence and co-evolution, which help to gain adaptability (Camarinha-Matos, 2009; Camarinha-Matos, Boucher, & Afsarmanesh, 2010; Daidj, 2011). According to the OECD (1997), SI is geographically centered, and performs surveys and cluster analysis. With respect to IE, "A business ecosystem goes beyond the core business agents (direct suppliers, core contributors and distribution channels) to embrace the whole supply chain, as well as other indirect agents and stakeholders."

Core discipline and theoretical basis – IE is predominantly found in publications focusing on management and technology concepts (complex systems), while SI has a strong presence in publications focused on economic theories (learning economy and knowledge economy). As postulated by the original contributors, both IE and SI are applications of System Thinking (Rakas & Hain, 2016). Both theories commonly involve the analysis of three aspects: the understanding of innovation activities, the role of the agents involved, and the interaction and resulting networks between them.

Boundaries and network boundaries - The aspect of regional localization is a relevant factor for the SI theory (Niosi et al., 1993). There are three ways in which we can identify boundaries of SIs: spatially/geographically, sectorally and functionally (Edquist, 2001). In the IE

theory, virtuality is a fourth accepted facet. As with a biological ecosystem, the main attribute of an IE is the heterogeneity of the actors, who pursue different objectives with different strategies. Interactions within an IE can be identified and classified in several ways, depending on the interests (shared purpose), the strategies of collaboration, shared resources and capacities involved; they are therefore complex and dynamic (Letaifa et al., 2013; Moore, 2013). The networks analyzed in the SI theory are found into two classes: the network of institutions in the public and private sectors (Freeman, 1987). The IE theory, on the other hand, considers networks as any business that is evolving in collaboration (Adner, Oxley, & Silverman, 2013; Moore, 2013).

Industry role - One of the most striking differences between the two theories is the role of industry-level analyses. In the SI theory, industry segments are important actors in the transformation of scientific knowledge into products and services (Lundvall, 2007b). In the IE theory, the industry segments does not have any role *per se*, and the segments are not units of analysis (Moore, 1996). Instead, the IE theory measures the individual relationships among the players (Thompson, Decker, Hardash, & Summers, 2012), which, in some cases, are clustered within a specific industry segment, though not necessarily.

Table 5 - Comparative Meta-Synthesis Framework: Framework Structure

Framework	***Comparative framework***	
	SI	**IE**
Scientific approach	Grounded Theory (Lundvall, 2005)	Grounded Theory (Letaifa et al., 2013)
Core discipline	Economy	Management
Theoretical basis	Learning economy Knowledge economy Evolutionary economy System Thinking	Complex Systems System Thinking Resource-Based Theory Evolutionary economy
Boundaries (the firm's perspective)	Sub-regional, national (most relevant), pan-regional and International	Global
Network boundaries	The network of institutions in the public and private sectors	One business collaboration agreement in a complex arrangement without borders; may include competitors
Industry role	An important protagonist in the transformation of scientific knowledge into products and services	The concept of industry is irrelevant and outdated
Approaches to analyzing	Firm-level innovation surveys Cluster analysis and	Network effect Network value

Patterns of knowledge flows	Shared Purpose Value Co-creation BEAM (business ecosystem analysis and modelling) Value creation in innovation ecosystems Constructs, Configurations, and the Nurturing Process

5.4 Cross-fertilization between the theories

As is evident from the previous analyses in this paper, SI and IE were developed within quite different contexts, and therefore they aim at explaining different dynamics. SI was developed mainly in the context of traditional manufacturing and incremental learning via SDI and DUI. We have a capital-intensive infrastructure in place and wonder how to design institutions that facilitate such learning processes. In IE, however, we look at San Francisco Bay Area dynamics within very dynamic and young industries, and also a novel and rapidly changing technology landscape (SFCED, 2015). In that way, we can see potential complementarities with respect to adjusting SI to new economic paradigms. In this article, other elements of complementarity have been identified and will be analyzed, but for this it is necessary to return to the objective of this article and to specify how the proposal of cross fertilization was developed: the main aim of the paper is to clarify to what extent the SI and IE literature are complementary and could benefit from cross-fertilization. The purpose of this cross-fertilization is to identify interactions or interchange that are mutually beneficial and productive for both theories. In order to enable this cross-fertilization, a comparative analysis was developed according to the theoretical framework (table 1) that composes each theory. Seminal articles, founding authors and major research communities were studied and compared. From the elements in common, a set of propositions of cross fertilization was elaborated considering three key elements: the interactions, the evolutionary theories and the building blocks of each theory.

Cross-fertilization: interactions

The results of the comparative analysis show reciprocity between the two theories regarding the understanding of the phenomenon of innovation when its dynamic elements (actors or processes) are analyzed according to their interactions. These interactions occur in a scenario common to both theories: technological change in environments conducive to innovation. In this way, the

interactions can constitute a cross fertilization link in both theories. First, in IE theory the concept of interaction requires a more structured definition that could be improved by inserting the concept of learning economy through the knowledge flows coming from the theory of innovation systems. On the other hand, the idea of institutional relationships coming from SI is based on a logic of economic geographic performance and lacks the understanding of more complex environments contemplated in IE. An example to be adapted in SI theory would be the possibility of understanding the effects of interactions in a context based on technological platforms that are not limited to regional or national borders.

Cross-fertilization: evolutionary theories

Evolutionary economics is part of mainstream economics as well as a heterodox school of economic thought that is inspired by evolutionary biology (Hodgson, 1993; Hodgson, Samuels, & Tool, 1994). Evolutionary economics deals with the study of processes that transform the economy for firms, institutions, industries, employment, production, trade and growth within, through the actions of diverse agents from experience and interactions, using evolutionary methodology (Simandan, 2012). Both theories use hypotheses based on evolutionary theories. One of the points where SI could benefit from IE's fundamentals would be the adoption of a variable of understanding (hypotheses) of innovation strategies in collaborative networks (best practices) in a global context and not restricted to geographic regions. This variable would seek to identify actors and networks of collaboration (external to the geographic area) with the power to influence the national or local innovation scenarios and consequently the impact on the policies on the agenda. From the point of view of IE, the influence of political actions is practically ignored. The adoption of analyzes of government actors as support for the expansion of *innovation communities* would be a major contribution of IS to IE theory. Moreover, new economic paradigms such as Virtual currencies, FinTech, Crowdfunding and others, are analyzed through perspectives of IE and may contribute to the evolution of the theoretical-conceptual framework of SI.

Cross-fertilization: building blocks

In the comparative analysis of the scientific constructs (building blocks) of IE and SI, it was noted that both use the methodology known as Grounded Theory. According to Glaser (1992), the strategy of Grounded Theory is to take the interpretation of meaning in social interaction on board and study "the interrelationship between meaning in the perception of the subjects and their

action". Another goal of a grounded theory is to discover the participants' main concern and how they continually try to resolve it. The questions the researcher repeatedly asks in grounded theory are "What's going on?" and "What is the main problem of the participants, and how are they trying to solve it?" (Glaser, 1978).

Grounded theory researchers are interested in patterns of action and interaction between and among various types of social units (i.e., "actors"). IE and SI theories have as a common factor the study of the phenomenon of innovation and its actors. IE and SI seek from different perspectives to understand and contribute to the challenges of innovation as a permanent element in the socio-economic and technological scenario. Although they have different starting points and objectives, they both start from the same methodological construction process and, using the same lenses, can integrate their research communities in seeing and constructing their theories. In the context of SI theory, it is important to note that the concepts of governance, resilience, power generation, coopetition and competition are not particularly well-developed in SI, and their consideration might be a fruitful path for SI theory improvement, inspired by IE.

Table 6 - Comparative Meta-Synthesis Framework: The interaction elements found between the two theories

Concepts		
	SI	**IE**
Key concepts	"...The elements and relationships which **interact in the production, diffusion and use of new, and economically useful, knowledge** ..." Lundvall (1992)	"An economic community supported by a foundation of **interacting organizations and individuals** — the organisms of the business world" Moore (1993)
Logic unit	Technological and economic performances	Opportunity environment Platforms
Literature (sources)		
	SI	**IE**
Key topics	Innovation	Strategy, Innovation
Inspirations	According to Lundvall (2007b): Neo-Schumpeterian theories	Economic evolutionary theories of Nelson, R., and Winter (1982)
Framework		

	SI	IE
Scientific approach	Grounded Theory (Lundvall, 2005)	Grounded Theory (Letaifa et al., 2013)
Theoretical basis	Evolutionary economy System Thinking	Evolutionary economy System Thinking

Other results of this research show possibilities of cross-fertilization through some initiatives that require the understanding of some contexts that will be detailed below.

In SI, we find several articles showing a mature self-criticism in search of improvements. As an example, we have the article "National innovation systems - analytical concept and development tool" that deals with the maturity and applicability of the theory in empirical terms. On the other hand, we have in IE an emerging theory that is more focused on the development of two types of research:

- The proposal of analytical tools developed for processes of strategic decision (Ecosystems Value Mapping and Analysis – Cambridge Service Alliance) or for operability of projects of technological innovation (6C Framework – Cambridge University),
- The deepening of the epistemological and ontological bases for the scientific justification of its originality in terms of school of thought. The works developed in Cambridge and by the *French school of IE* (Parisot & Thierry, 2017b) in the article “Une lecture Lakatosienne de l’approche par les Ecosystemes d’affaires” have shown commitment in research in the thematics of IE.

In terms of academic production, this research has shown that the number of case-study publications in IE are still few in number compared to SI studies analyzing innovation systems in each country. It would be interesting to evaluate if the cluster analysis used in SI can be a source of inspiration for IE research.

A similarity was found showing that these two different theories are applications of System Thinking approach. Another finding, which has not been mentioned in previous research on the topic, is that the construction of the initial concepts of the IE theory is originally rooted in several SI elements.

A research agenda focused on the analysis of cross citations between articles of the two communities was also identified as a source of responses to identify cross-fertilization benefits.

6. Conclusions

The results of this research were presented in the item "Cross-fertilization between theories" and non-exhaustively presented the numerous opportunities of cross-fertilization between the theories that were compared and analyzed.

Based on a review of literature, the analysis of each theory was developed on an ontological framework built from the meta-synthesis technique integrating the seminal results of the theories that were compared. The choice of methodology was to identify conceptual terms as a central reference and to build an ontological framework in order to adapt to each theory in a well structured way.

The meta-synthesis was an ideal choice since the theories under study were constructed under the logic of Grounded theory, the concepts and categories of which are well established. In this way it was possible to clearly visualize the strengths of the chosen methodology.

The comparative analysis between the theories included in the above inventory (table 1, 2 and 3) were made on many aspects, varying from ontological concepts (logic unit, key concepts, related terms, etc.) to formal structure (scientific approach, theoretical basis, approaches to analyzing, etc.) and including the major research communities (Harvard University - Berkman Centre for Internet & Society, University of California – Berkeley, University of Cambridge - Cambridge Service Alliance, Aalborg University, Tsinghua University, SPRU (UK), Stanford University).

Numerous difficulties were encountered in the course of the research. Distinguishing which papers used the term ecosystem as metaphor or as Moore's theory was a great challenge. Soon after, several articles were identified quoting Moore and his theory but disregarding all the framework and existing theoretical elements. Numerous were those articles mixing theory and metaphors. In the context of SI, the difficulty was to identify more recent articles in the subject, since the number of publications in the subject is decreasing.

Finally, cross-fertilization analysis was performed observing similar and interactable elements.

Suggestions and practical applications

In the course of this research, many factors were identified as potential elements for a possible continuity of cross fertilization research.

These reflections and practical propositions are the result of the analysis and the identification of an opportunity to evolve concepts and correlations that await a deepening of this research that is potentially rich in answers. In this way, we conclude proposing a trajectory to be followed to deepen this research:

- A research agenda can be proposed by identifying gaps to be filled between the two theories as well as an analysis based on other comparative methods;
- Opening to the intersection of theories in conferences and other events of research communities;
- Development of collaborative works among the researchers in the subject;
- Improve the policy making process by incorporating IE's dynamic business and market vision
- Elaborate a study of trends in innovation, observing the socio-economic and technological aspects for a new cross-fertilization according to the current needs;
- Elaborate case studies to identify empirical results and limitations in the case of attributes resulting from cross-fertilization

Limitations - We were exposed to some limitations in this paper. Other aspects could be used to compare the theories under study, but without a structured criterion through the proposed framework, we run the risk of not prioritizing what is essential in a literature review.

Adjacent, contiguous, concurrent, or similar theories to the theories compared in this research were not considered in order to respect the scope, objectives, and method of this article.

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